Description

METHOD AND APPARATUS FOR REGENERATING NOx ADSORBERS

Technical Field

[01] This invention relates generally to aftertreatment, and in particular to the regeneration of NOx adsorbers.

Background

[02] As emissions from internal combustion engines have become more of a focus for engine manufacturers, an increasing number of designs use NOx adsorbers, also known as a Lean NOx trap ("LNT"), in the exhaust path of the engine. The NOx adsorber adsorbs some of the NOx created in the combustion process, thereby reducing the amount of NOx released into the atmosphere.

[03] The known NOx adsorbers, however, have a tendency to fill up in a relatively short period of time; sometimes as quickly as a few minutes. One technique that counters this degradation is the periodic regeneration of the NOx adsorber, commonly implemented by running the engine in a rich condition for a predetermined period of time. Because most engines today are lean burn engines, however, while the NOx adsorber is regenerating in this rich condition, additional fuel is being used. This correlates to a reduction in the gas mileage/fuel economy for the engine. Due to the high frequency of regeneration, this reduction can equate in some operating conditions to be as large as approximately 4%. To put this in perspective, many engine manufacturers today consider an improvement in fuel economy of tenths of a percent to be meaningful.

Summary of the Invention

[04] The present invention provides methods and apparatuses for regenerating a NOx adsorber coupled with an exhaust of an engine. An actuator drives a throttle valve to a first position when regeneration of the NOx adsorber is desired. The first position is a position that causes the regeneration of the NOx adsorber. An actuator drives the throttle valve to a second position while regeneration of the NOx adsorber is still desired. The second position being a position that is more open than the first position and operable to regenerate a NOx adsorber.

Brief Description of the Drawings

[05] Figure 1 shows a graph of throttle position and lambda for an internal combustion engine according to one embodiment of the invention.

Detailed Description

[06] Figure 1 shows a graph 10 of throttle position and lambda for an internal combustion engine according to one embodiment of the invention. The x axis represents time, in seconds, and the y axis represents both the lambda value for the inlet air of an internal combustion engine and the throttle position for that same engine (a throttle position of 1 is fully open, 0 is fully closed; lambda value of 1 is stoichiometric).

[07] Line 12 represents the throttle position according to one embodiment of the invention. During normal engine operation, the engine typically operates in a "lean condition" (lambda greater than 1). In this situation, the throttle position may typically be wide open, as seen during seconds 1-3. When regeneration of the NOx adsorber is desired, as indicated by a sensor or sensors on the engine, for example, the throttle position is changed to a more closed position sufficient to cause the air to fuel ratio (lambda) to become "rich" (a fuel to air ratio that is less than stoichiometric). In one embodiment of the

invention, this first position may be a valve position that is approximately 20% open, although other percentages could also be used. This "rich condition" regenerates the NOx adsorber by ways known to those skilled in the art, and will not be repeated here.

[08] Typically an engine control system (not shown) will determine a desired steady state "rich" condition to cause the regeneration of the NOx adsorber, and its corresponding throttle position. When regeneration of the NOx adsorber is desired, the throttle position is driven to a position that is more closed than the steady state "rich" throttle position, as seen in seconds 3-4. In one embodiment of the invention, this second position may be a valve position that is approximately 25% open, although other percentages could also be used.

[09] After some first predetermined period of time, the throttle position is driven (*e.g.*, opened) to a second position, e.g., approximately a steady state "rich" throttle position, and maintained at that position for a second predetermined period of time. The second predetermined period of time is a time sufficient to allow the NOx adsorber to regenerate to some desired extent. The regeneration may be 100%, or some desired percentage less than 100%. In this example, the throttle position is held at the second position for approximately 5 seconds, although other durations could also be used.

[10] After the desired amount of regeneration of the NOx adsorber is achieved, the throttle position may be moved back to it's "lean" position for normal engine operation, as shown in seconds 9-15.

[11] Line 14 shows the throttle position for an engine not using the two-step process described above and labeled as line 12. Line 16 shows the corresponding lambda for the two-step throttle position line 12, according to one embodiment of the invention. Line 18 shows the corresponding lambda for the one-step throttle position line 14, according to one embodiment of the invention.

[12] It is worth noting that by using the two-step process (line 12), the overall duration when the engine is running "rich" may be decreased relative to

the one step process (line 14) and still achieve a similar degree of regeneration of the NOx adsorber. This can be seen by comparing the areas above the curve for lines 16 and 18. In this example, approximately 1 second may be shaved per regeneration period, although results may vary depending on the particular application. This reduction of 1 second in the "rich" operation of the engine can equate to approximately a .5% increase in fuel economy as compared to the process shown in line 14.

Industrial Applicability

[13] A sensor or sensors (not shown) for an engine can be used to determine when the regeneration of a NOx adsorber is desired by ways known to those skilled in the art. An engine control system (not shown) can then drive the throttle position to a point that is more closed than the steady state position that regenerates the NOx adsorber. After a predetermined period of time, the throttle position is opened to approximately the steady state position for regeneration. By using this two-step process, the throttle position is able to achieve a lambda less than 1 more quickly. This shortens the duration for regeneration and the time that the engine runs "rich", thereby potentially increasing the fuel economy for the engine.

[14] From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.